Physics 230

Homework Set 5

CQ1. Consider two identical containers, one is filled with helium gas and the other is filled with oxygen gas. Both gases are found to have the same root-mean-square speeds. How do their temperatures compare? Answer quantitatively!

CQ2. The average kinetic energy of the molecules in an ideal gas increases with the volume remaining constant. Which of the following statements *must* be true?

a) The pressure increases and the temperature stays the same.

b) The number density decreases.

c) The temperature increases and the pressure stays the same.

d) Both the pressure and the temperature increase.

CQ3. The rms speed is the

a) speed at which all the gas molecules move.

b) speed of a molecule with the average kinetic energy.

c) average speed of the gas molecules.

d) maximum speed of the gas molecules.

CQ4. If the temperature of an ideal gas is doubled and the pressure is held constant, the rms speed of the molecules

a) remains unchanged.

b) is 2 times the original speed.

c) is $\sqrt{2}$ times the original speed.

d) is 4 times the original speed.

P1. The mean free path of nitrogen molecules is 8.0×10^{-8} m when the gas is held at a temperature of 0.0°C and a pressure of 1.0 atm. Calculate the diameter of the nitrogen molecules.

P2. Consider a 5-particle gas of molecules with velocities given by

$$\begin{aligned}
\vec{v}_1 &= (15\hat{\imath} - 25\hat{\jmath} + 25\hat{k}) \text{ m/s} \\
\vec{v}_2 &= (20\hat{\imath} - 30\hat{\jmath} + 40\hat{k}) \text{ m/s} \\
\vec{v}_3 &= (-35\hat{\imath} + 20\hat{\jmath} - 10\hat{k}) \text{ m/s} \\
\vec{v}_4 &= (20\hat{\imath} - 30\hat{\jmath} - 30\hat{k}) \text{ m/s} \\
\vec{v}_5 &= (-20\hat{\imath} + 65\hat{\jmath} + 25\hat{k}) \text{ m/s} \qquad (1)
\end{aligned}$$

Calculate the

a) average velocity,

b) the average speed, and

c) the root-mean-square speed of the gas particles.

P3. A container of gas has a density of 1.24×10^{-5} g/cm^3 when the pressure of the gas is 1.01×10^3 Pa and its temperature is 0.00°C.

a) Calculate the root-mean-square speed of this gas?

b) Calculate the molar mass of the gas and identify the gas.

P4. 8.5 g of oxygen gas, with an initial temperature of 325∘C is placed in thermal contact with 3.5 g of helium gas, which has an initial temperature of 23∘C.

a) Calculate the initial and final thermal energies of each gas.

b) How much heat is transferred, and in which direction?

c) Calculate the final temperature.

d) Calculate the final pressure in each cylinder.

P5. A monatomic gas is isochorically heated until the gas temperature triples. Do each of the following quantities change? If so, do each increase or decrease, and by what factor. If not, why not?

a) The root-mean-square speed.

b) The mean free path.

c) The thermal energy of the gas.

d) The molar specific heat at constant volume.

P6. 1.00 mol of helium gas starts at an initial state A, which is characterized by a pressure of 1.00 atm and a temperature 300.K. The gas undergoes an *isochoric heating* until it reaches a state B where the gas reaches a temperature of 600.K. The gas then undergoes an *adiabatic expansion* until it reaches a state C where the gas reaches it's initial pressure. Finally, the gas undergoes an *isobaric compression*, which brings the gas back to its initial state A .

a) Calculate the pressure and volume of the gas at states B and C.
A, B, and C, respectively.

b) Draw a pV diagram showing this process. This diagram needs to include axes labels and an arrow indicating the direction traversed between the initial and final points on the pV curve. Also, indicate the temperature at each point.

c) Calculate the heat, Q, work done on the gas, W, and thermal energy change, ΔE_{th} for the gas as it goes through *each* of the three aforementioned processes.